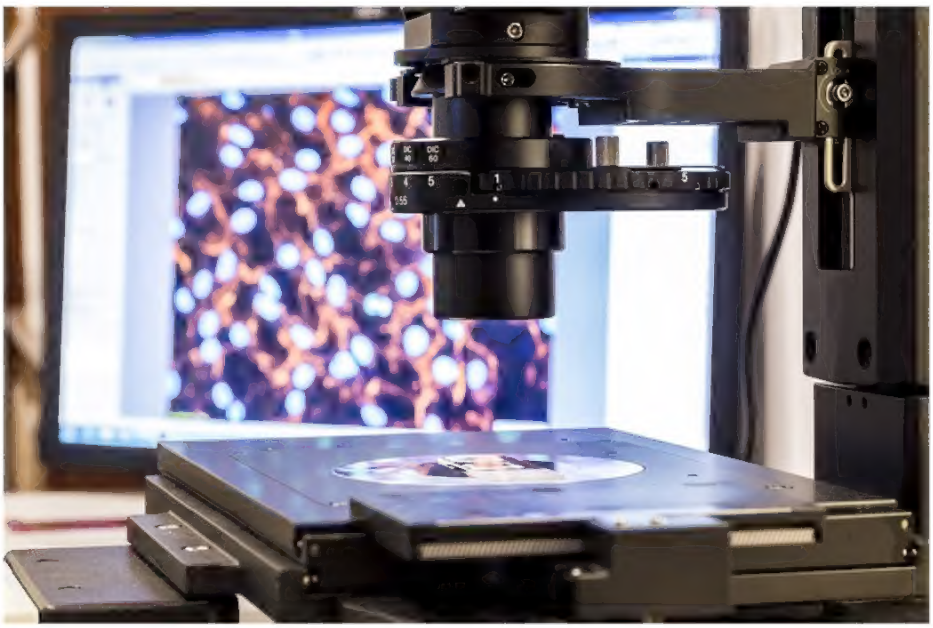
FM-AFM microscope



An FM-AFM (Frequency Modulation Atomic Force Microscope) is a type of non-contact atomic force microscope that measures the changes in the resonant frequency of an oscillating cantilever as its sharp tip interacts with a sample surface. This frequency shift is proportional to the conservative force gradient, allowing for extremely sensitive imaging and the measurement of surface properties. FM-AFM is known for achieving high-resolution images without direct mechanical contact with the sample.

FM-AFM microscopes are applied in diverse fields, including biology for imaging cells and DNA, materials science to characterize polymers and

metals, nanotechnology for studying nanomaterials and fabrication, and semiconductor manufacturing for inspecting and etching wafers. The technique's ability to provide high-resolution images of surfaces in their native environment, alongside measurements of mechanical and electrical properties, makes it valuable across many scientific and industrial applications.

- **How it Works:**

1. Oscillating Cantilever:

A sharp tip is mounted on a micro-oscillator called a cantilever. This cantilever is excited to oscillate.

2. Tip-Sample Interaction:

As the oscillating tip approaches the sample surface, the forces between them (like van der Waals forces) cause the resonant frequency of the cantilever to change.

3. Frequency Modulation:

A feedback loop adjusts the oscillation frequency to keep it constant at its resonant frequency.

4. Frequency Detection:

This change in frequency is detected and recorded.

5. Image Generation:
The recorded frequency data is used to create a topographic map of the sample surface with atomic or subatomic resolution.
- Key Features & Applications:
*** Non-Contact Imaging:** The tip never directly touches the sample, preventing sample damage.
*** High Resolution:** Capable of achieving atomic-level resolution imaging.

*** Mechanical Property Measurement:** Can be used to measure the microrheological properties (elasticity and viscosity) of soft samples like tissues.
*** Versatility:** Can operate in both vacuum and liquid environments, although liquid operation has required specific adaptations.
- Benefits:
*** Extreme Sensitivity:** Detects conservative force gradients with high precision.
*** Stable Operation:** Allows for the use of high-quality factor (high-Q) cantilevers without restricting bandwidth.

* **Quantitative Data:** Enables the direct determination of interaction forces and energy from frequency shifts.

- **Specific Applications by Field:**
* **Biology and Medicine:**
1. **Imaging Biological Samples:**
Visualizing cells, tissues, proteins, and DNA structures.
2. **Mechanical Properties:**
Measuring the elastic modulus and other

mechanical characteristics of cells and extracellular matrices.
3. **Biochemical Interactions:**
Studying receptor-ligand interactions and chemical responses in living cells.

- **Materials Science:**
* **Surface Characterization:**
Imaging the topography and structure of a wide range of materials, including polymers, ceramics, composites, and metals.

*** Mechanical Properties:**
Measuring surface adhesion, hardness, friction, and other properties.
*** Tribology:**
Studying friction and wear at the nanoscale.

- Nanotechnology:
*** Nanomaterial Analysis:**
Investigating the structure and properties of nanoparticles and other nanomaterials.
*** Nanofabrication:**
Using the AFM to create and manipulate nanostructures.

- Semiconductors and Electronics:
*** Inspection and Etching:**
High-resolution imaging for inspecting and etching silicon wafers and other semiconductor devices.
*** Electrical Characterization:**
Measuring nanoscale electrical conductivity, dielectric breakdown, and doping profiles in integrated circuits.

- Environmental and Surface Chemistry:

*** Microplastic and Pollutant Detection:**

Visualizing the morphology
of microplastics, detecting pollutants in the environment, and studying nanotoxicology.

*** Surface Energy and Adhesion:**

Measuring surface energy and adhesion forces.

- Atom and human body:

https://archive.org/details/atom-and-human-body

By: Haytham Zeidan

https://archive.org/details/@wazefapress

Resources:

https://scientaomicron.com/en/technology/FM-AFM/111

https://www.sciencedirect.com/science/article/abs/pii/S0167572902000778

https://www.nanofunction.org/frequency-modulation-afm

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https://m.made-in-china.com/product/FM-Nanoview-1000-Afm-Atomic-Force-Microscope-789256055.html

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https://www.prior.com/applications/atomic-force-microscopy

https://pmc.ncbi.nlm.nih.gov/articles/PMC3055745/

https://cse.lmu.edu/research/instrumentsandfacilities/atomicforcemicroscopeafm/

https://www.nanbiosis.es/atomic-force-microscopy-afm-principles-modes-and-emerging-applications-in-nanotechnology-and-biomedicine/